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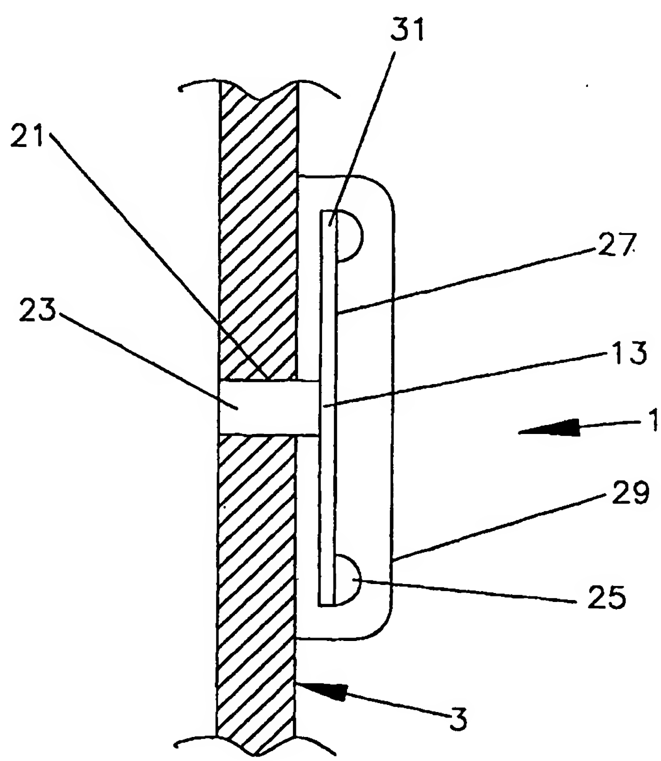
(54) Title: VIBRATION EXCITERS

(57) Abstract

A vibration exciter (1) for bending wave panels (3) is described. The exciter includes an electrostrictive bender element (13) including at least one layer of electrostrictive material such as lead magnesium niobate titanate (PMNT).



TITLE: VIBRATION EXCITERS

DESCRIPTION

TECHNICAL FIELD

The invention relates to vibration exciters and more particularly to vibration exciters for loudspeakers comprising resonant panel-form acoustic radiating elements.

BACKGROUND ART

It is known from WO97/09842 to suggest a resonant panel-form loudspeaker. Such loudspeakers have become known as distributed mode or "DM" loudspeakers.

Most such loudspeakers of reasonable quality use moving coil or moving magnet exciters. Piezoelectric exciters have been proposed, but do not provide enough power delivery into the panel for many applications; this problem is particularly acute at low frequencies.

There is thus a need for an improved exciter that

retains advantages of a piezoelectric exciter, but which alleviates this problem.

According to the invention there is provided an inertial exciter for driving a bending wave panel, comprising

a planar element,

a mass fixed to the planar element,

a coupling region for coupling to the bending wave panel, the coupling region being spaced away from the mass,

characterised in that the planar element is an electrostrictive bender comprising a layer of electrostrictive material.

Recent work has demonstrated improved electrostrictive materials, in which an applied voltage causes the material to stretch. In particular, lead magnesium niobate titanate has now been prepared in high purity.

Such materials can deliver higher sensitivity (movement as a function of voltage), than piezoelectric materials. However, the advantage of piezoelectric devices of a small number of parts is retained.

The electrostrictive bender may comprise an electrically conductive counterlayer, a layer of electrostrictive material extending over the counterlayer and an electrode on the opposite side of the layer of electrostrictive material to the counterlayer.

The conductive counterlayer may be of metal, or alternatively any material with a metallic electrode

deposited thereupon.

Alternatively, the electrostrictive bender may comprise a first layer of electrostrictive material, a second layer of electrostrictive material, a common electrode layer sandwiched between the first and second layers of electrostrictive material, a first layer electrode on the opposite side of the first layer of electrostrictive material to the common electrode, and a second layer electrode on the opposite side of the second layer of electrostrictive material to the common electrode.

The layer of electrostrictive material preferably comprises lead magnesium niobate titanate.

There may be provided a bending wave panel having an exciter as described above coupled to the panel to excite bending waves in the panel.

The electrostrictive bender may be prestressed. This may increase the sensitivity of the device (sound output for unit input voltage), and may also increase the sensitivity of the device.

In a second aspect, a loudspeaker comprises a panel capable of supporting bending wave oscillations, a layer of electrostrictive material bonded directly to the panel over an area of the panel, and electrodes sandwiching the layer of electrostrictive material so that a voltage applied to the electrodes causes the electrostrictive material to stretch and bend the panel.

In a third aspect, a method of producing an acoustic

output, comprises providing a loudspeaker as above and supplying a drive signal made up of the sum of a constant offset voltage and a small acoustic signal.

Means may be adopted to mount the exciter on a member to be vibrated, the arrangement being such that a substantial part of the device is spaced from the member for movement relative thereto.

The device may be of lead magnesium niobate titanate (PMNT). The device may be disc-like. The mounting means may be disposed centrally of the disc and the mass may be secured to the periphery of the device. Alternatively the peripheral margin of the disc-like device may be fixed to the member to be vibrated, and the mass may be secured to the centre of the device.

A resilient member may be employed to attach the mass to the device.

Devices as described above may be attached to opposite sides of the member to be vibrated and coupled together by a common mass to operate in push/pull mode.

From another aspect the invention is a loudspeaker comprising a panel-form resonant member forming an acoustic radiator, characterised by a vibration exciter as described above coupled to vibrate the radiator.

BRIEF DESCRIPTION OF DRAWINGS

The invention is diagrammatically illustrated, by way of example, in the accompanying drawings, in which:-

Figure 1 is a diagram of a first embodiment of vibration exciter;

Figure 2 is a diagram of an implementation of a bender element forming part of the vibration exciter according to the invention;

Figure 3 is a diagram of an alternative implementation of a bender element;

Figure 4 is a diagram of a second embodiment of vibration exciter;

Figure 5 is a diagram of a third embodiment of vibration exciter;

Figure 6 is a diagram of an fourth embodiment according to the invention, and

Figure 7 shows a mobile telephone according to the invention.

BEST MODES FOR CARRYING OUT THE INVENTION

Figure 1 illustrates an embodiment of an electrostrictive vibration exciter 1 in which a planar electrostrictive bender element 27 has a coupling region 13 at its centre which is mounted on one end of a lightweight rigid cylindrical block 21 of rigid foam plastics which is rigidly fixed in an aperture 23 in a sound radiator panel 3 e.g. by means of an adhesive.

Said one end of the block 21 projects from the face of the panel 3 so that the periphery region 31 of the element 27 is freely suspended adjacent to a face of the panel 3. An annular ring 25 of plastics, e.g. mineral loaded polyvinylchloride, acts as a mass and is rigidly fixed to the periphery 31 of the element 27.

The planar electrostrictive bender element 27

includes a layer of electrostrictive material. Electrostrictive material expands and contracts when voltage is applied and the arrangement of the inertial transducer requires that the planar element bends. One way of achieving bending is shown in Figure 2. The planar element 27 includes a metal plate 41 to act as a counterlayer. A layer of electrostrictive material 43, for example lead magnesium niobium titantate, is deposited on the metal plate 41, and an electrode 45 is deposited on the opposite side of the layer of electrostrictive material 43 to the counterlayer 41.

When a voltage is applied between the electrode 45 and the metal plate 41 the layer of electrostrictive material expands along one axis (and contracts along the others). This expansion relative to the fixed counterlayer 41 causes the planar element 27 to bend.

It should be noted that in the electrostrictive effect the expansion of electrostrictive material is proportional to the square of the electric field. Accordingly, the sign of the applied voltage is irrelevant and the material can only stretch along its main axis, shrinking along the perpendicular axes at the same time. When voltage is removed, the planar element springs back because of the resilience of the metal counterlayer 41.

When the transducer is energised with an electrical signal at acoustic frequencies, the device 27 vibrates and launches bending waves into the panel 2 to cause the panel to resonate and produce and radiate an acoustic output.

The exciter 1 may be covered by a domed housing 29 which is fixed to the panel 3 to protect the exciter.

An alternative form of electrostrictive bender element 27 is shown in Figure 3. A first electrostrictive layer 51 and a second electrostrictive layer 53 sandwich an electrode 55. First and second outer electrodes 57,59 are provided on the outside of the first and second electrostrictive layers 51,53 respectively

In such an arrangement the bender can bend first one way then the other as a voltage is applied across the first and then the second electrostrictive layers. This can be achieved with a single signal by providing a first diode 61 in series with the first outer electrode and a second diode 63 in series with the second outer electrode, the first and second diodes having opposite polarity.

The electrostrictive vibration exciter 9 of Figure 4 comprises a disc-like ceramic device 27 e.g. of PMNT fixedly mounted by its periphery region 31 on the surface of a panel 3 e.g. with the aid of an adhesive, with the central portion of the device 27 freely suspended over a cavity 33 in the panel 3 such that only the periphery 31 of the device 27 is in contact with the panel. A mass 25 e.g. of plastics material is attached to the centre of the device 27 with the interposition of a damping pad 35 of resilient material, e.g. of an elastic polymer.

Thus an acoustic signal applied to the device will cause the device to vibrate and thus to launch bending waves into the panel. The drive effect of the exciter is

enhanced by loading the device 27 with the mass 25 to increase its inertia.

The electrostrictive vibration exciter arrangement of Figure 5 is similar to that of Figure 4 except that in this embodiment a pair of electrostrictive bender elements 27 are attached on opposite sides of a cavity 33 through a panel 2 to operate in push/pull mode. In this arrangement, the centres of both devices 27 are connected together by a common mass 25. Resilient damping pads are positioned between each device 27 and the mass 25.

In a further embodiment, a PMNT element may be bonded to the panel on one or both sides of the panel as shown in Figure 6. In this example the panel 3 itself functions as the counterlayer. A first electrode 71 is deposited on the panel 3. A layer of electrostrictive material 73 is deposited on the first electrode, and a second electrode 75 is deposited on the layer of electrostrictive material 73.

An electrostrictive device has a square law relationship between the displacement and the applied electric field - the displacement is proportional to the square of the field. Thus, for a linear response, some form of correction is required.

The simplest form of correction is to apply a d.c. voltage bias to the input signal.

A precorrection network of diodes can be used.

Either or both of the above could be used together with analogue or digital signal processing of the signal

applied to the electrostrictive exciter.

The electrostrictive exciter has particular application in a mobile telephone (Fig.7). A loudspeaker driven by an electrostrictive exciter (1) is located in the telephone (81) so that it is adjacent to the ear of the user of the telephone when the telephone is in normal hand-held use.

For such normal hand-held operation with the loudspeaker adjacent to the ear the exciter can be operated by the receiver (83) with a large d.c. offset and a small a.c. signal to produce a reasonable quality sound.

However, the mobile telephone can also be used to produce an 80db sound at 10cm with 10% distortion: in this mode the mobile telephone can be placed, for example, on a desk, and heard by a user seated at the desk. This can be done by driving the exciter from the receiver with a larger a.c. signal retaining the d.c. offset.

The same transducer can be used for the ringer/buzzer. For this application distortion is not relevant, and so the transducer can simply be driven with a still larger a.c. signal directly from a ringer (85).

Of course, the exciter can also be used simply as an audible warning device; again the distortion is not relevant.

The advantage of using an electrostrictive exciter in the above applications is the greater sensitivity of the loudspeaker thus produced. This is due to the increased size of the electrostrictive effect as compared with the

piezoelectric effect hitherto used.

A further possibility is to exploit the non-linearity of the electrostrictive exciter by using it to demodulate a signal. For example, a high frequency signal may be prepared modulated by an acoustic signal at lower audio frequencies. The modulation may be amplitude or frequency modulation.

When such a signal is used to drive an electrostrictive exciter the non-linearity of the response acts to demodulate the audio frequency signal. Accordingly, a modulated signal can produce an acoustic output without any other components. This can be used to exploit the low (capacitative) impedance at high frequencies which in some circumstances may make driving the exciter easier a those frequencies than at low frequencies. Amplitude modulation is marginally preferable to frequency modulation, since it delivers a reduced number of sidebands.

INDUSTRIAL APPLICABILITY

The vibration exciters of the invention are relatively simple in construction and are effective in use.

CLAIMS

1. An inertial exciter for driving a bending wave panel, comprising

a planar element (27),

a mass (25) fixed to the planar element (27) in a first region (11) of the element,

a coupling region (13) for coupling to the bending wave panel, the coupling region (13) being spaced away from the mass (25),

characterised in that the planar element (27) is an electrostrictive bender including a layer of electrostrictive material (43, 51, 53).

2. An inertial exciter according to claim 1 wherein the electrostrictive bender (27) comprises

a conductive counterlayer (41), a layer of electrostrictive material (43) extending over the counterlayer (41) and

an electrode (43) on the opposite side of the layer of electrostrictive material (43) to the counterlayer.

3. An inertial exciter according to claim 1 wherein the electrostrictive bender comprises

a first layer of electrostrictive material (51),

a second layer of electrostrictive material (53),

an common electrode layer (55) sandwiched between the first and second layers of electrostrictive material (51, 53),

a first layer electrode (57) on the opposite side of the first layer of electrostrictive material (51) to the

common electrode (55), and

a second layer electrode (59) on the opposite side of the second layer of electrostrictive material (53) to the common electrode (55).

4. An exciter according to any preceding claim wherein the layer of electrostrictive material (43, 51, 53) comprises lead magnesium niobate titanate.

5. An exciter according to any preceding claim wherein the electrostrictive bender is prestressed.

6. A loudspeaker comprising

a bending wave panel (3), and

an exciter (1) according to any preceding claim.

7. A loudspeaker comprising

a panel (3) capable of supporting bending wave oscillations,

a layer of electrostrictive material (73) bonded directly to the panel over an area of the panel, and

electrodes (71,75) sandwiching the layer of electrostrictive material (73) so that a voltage applied to the electrodes causes the electrostrictive material to stretch and bend the panel.

8. A loudspeaker according to claim 7 wherein the layer of electrostrictive material (73) comprises lead magnesium niobate titanate.

9. A mobile telephone comprising

a loudspeaker (1,3) according to any of claims 6 to 8,

a ringer (83) connected to the loudspeaker producing

an electrical ringing signal at a first level,

a receiver (85) for receiving the incoming signal and supplying the signal to the loudspeaker together with a constant voltage offset,

wherein the receiver can operate in a loudspeaker mode in which the receiver supplies the signal at a second level, less than the first level, together with the constant voltage offset to produce acceptable distortion and a sound output of at least 70dB at 10cm, and a low-distortion mode in which the receiver supplies the signal at a third level, less than the second level, together with the constant voltage offset to produce a lower distortion level.

10. A method of producing an acoustic output, comprising

providing a loudspeaker according to any of claims 6, 7 or 8, and

supplying a drive signal made up of the sum of a constant offset voltage and a small acoustic signal.

Figure 1.

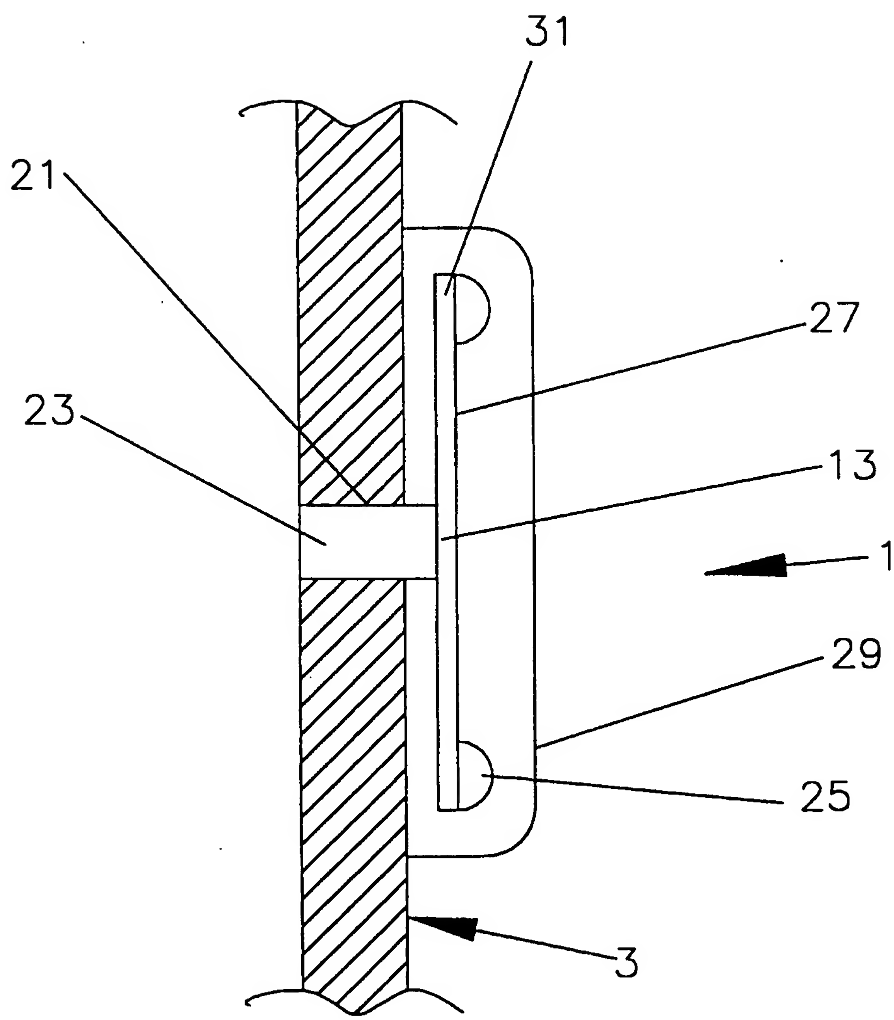


Figure 2

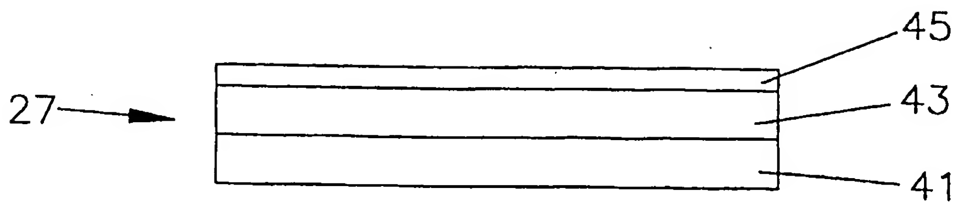


Figure 3.

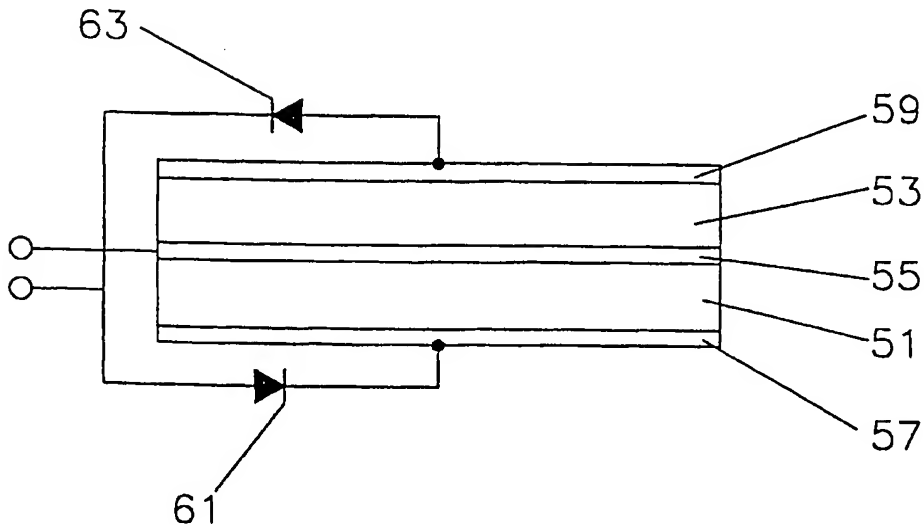


Figure 6.

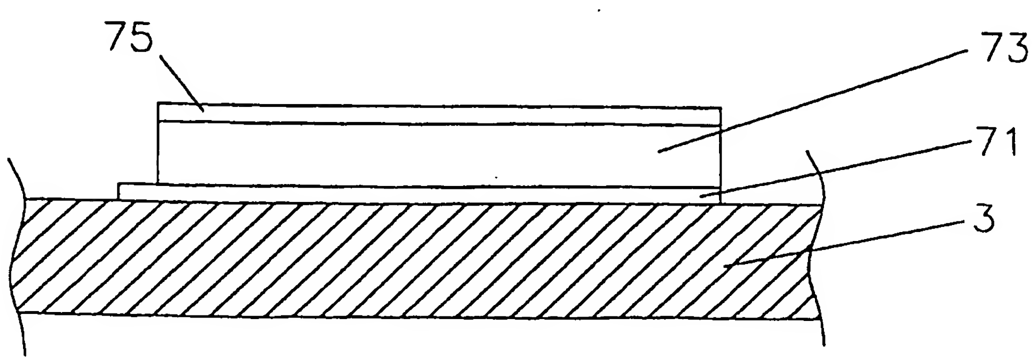


Figure 4.

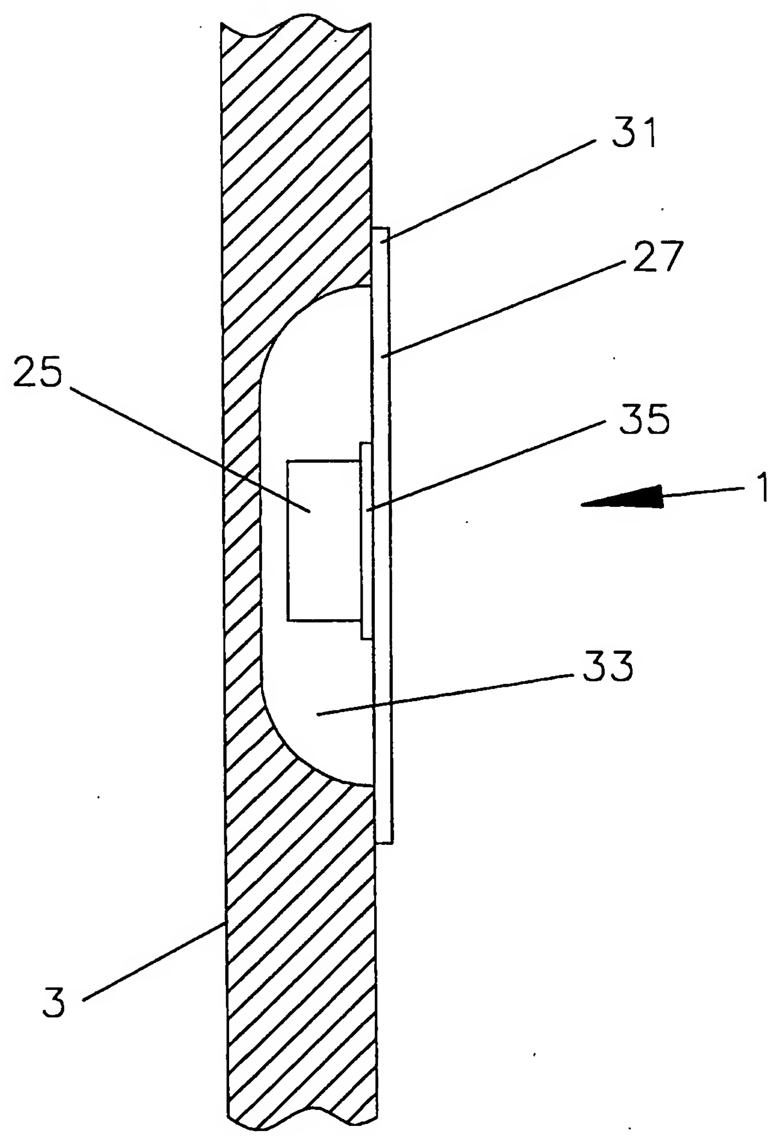


Figure 5

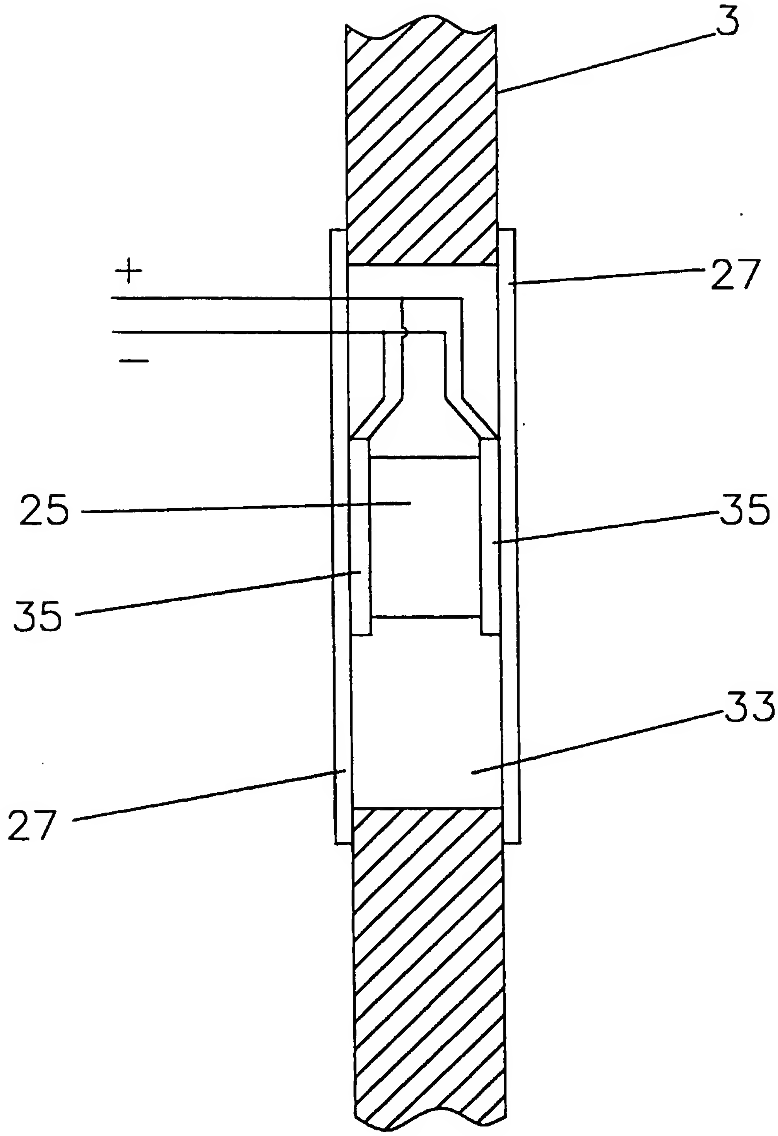


Figure 7.